Experimental Evaluation of an Intelligent Tutoring Hypermedia

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SUMMARY
Several hypermedia learning environments have been developed in the last years, with the objective of helping students to acquire specific concepts on a given topic, as well as problem-solving abilities. However, there are still many different and sometimes conflicting claims about learning effectiveness by means of such environments. We present an empirical evaluation of a learning hypermedia with a tutorial component that exploits Artificial Intelligence techniques. This hypermedia, called Logiocando, has been designed to be used by a special category of users, namely children of the fourth level of primary school, to help them to learn basic concepts of logic. This category of users demands special attention to usability of the hypermedia. For this reason, project and development of the hypermedia have been carried out following a strict user-centred methodology, in order to build a system that satisfies clear usability objectives. The aim of the controlled experiment here reported was to evaluate the learning effectiveness of Logiocando and to estimate the difference between two approaches: the computer-based one, that uses a hypermedia system, and the traditional one, that uses the typical lesson in classroom. The results have shown that the hypermedia can certainly be considered a valid support in the process of learning and deepening a topic.

KEYWORDS: Intelligent tutoring hypermedia, usability, user-centred design, learning effectiveness.

INTRODUCTION AND MOTIVATION
The use of computers in education is a field to which a lot of research is currently addressed. The aim is to design and develop hypermedia learning environments that can really help students to acquire specific concepts on a given topic, as well as problem-solving abilities.

Whether multimedia/hypermedia learning environments actually enrich student learning is a question still debatable [9, 21]. Actually, there are many different and sometimes conflicting claims about learning effectiveness by means of such environments [2, 3, 13, 22]. Bagui refers to several studies showing that computer-based multimedia can help people learn more information and learn it more quickly compared to the traditional lectures in classrooms [1]. As main reason for explaining the increasing learning using multimedia, Bagui indicates “the parallels between multimedia and the “natural” way people learn, as explained by the information processing theory”. Other mentioned reasons are: “multimedia allows interactivity with the computer, multimedia is flexible, multimedia has a rich content, multimedia has motivational effects, and multimedia allows better structured instruction” [1]. The study in [20] showed that multimedia computer-assisted language instruction was significantly more effective than teacher-taught classes in increasing the English proficiency level of students who averaged 21 years in age. Another study has reported no differences in learning between a group of participants which used a hypermedia manual for instructing about mechanical systems and the other group which used a traditional printed manual [6].

However, other studies have shown that hypermedia systems per se are not always efficient learning systems because the navigational freedom they offer is often overwhelming, while they tend to ignore individual characteristics. Only students capable of planning their own learning paths can take full advantage of this environment; indeed, building up their own knowledge by finding which information is useful to acquire, and in what order, surely requires considerable ability [8, 10].

As pointed out by Schank [18, 19] and Roselli [14], methods and techniques of Artificial Intelligence provide a useful support for more efficient learning hypermedia, since they allow an opportune integration of the freedom of action of the learner with a more explicit control and guide, aiming to lead the learner toward valid learning goals. In other words, the hypermedia equipped with a tutor capable to appropriately drive the learner proved to be efficient learning systems in several studies that have been carried out. In particular, the work conducted in [14] by one of the authors of this paper showed the superior performance of the group of
participants that used a hypermedia system for learning logic programming embodying a rule-based tutorial component with respect to the group which used the same system without the tutorial component. Also in this case, as in the experiment conducted in [20], the participants were university undergraduate students. This is a special category of users, since they are usually very much motivated.

The work reported here is also an evaluation of a learning hypermedia with a tutorial component. The novelty with respect to the work in [14] is that, in this case, the hypermedia has been designed to be used by a special category of users, namely children of the fourth level of primary school. The work has been carried out in collaboration with teachers of the primary school, with the aim of creating educational software that may be useful for teachers and students in primary school classrooms, and integrated in the school curriculum. The chosen hypermedia domain is logic, which is considered a topic difficult to understand by children, but it is also very important as the basis for teaching mathematics. The hypermedia we have developed is called Logiocando, that in Italian means Playing with Logic. More details on Logiocando can be found in [16].

Because of the special category of users of this hypermedia, namely children, project and development have been carried out following a strict user-centred methodology, in order to build a system that satisfies clear usability objectives. The user-centred approach of Logiocando is described in the next section. Then, in the section titled Experiment, we describe the experiment carried out for evaluating the learning effectiveness of Logiocando and we discuss the results. Finally, in the last section we provide the conclusions.

USER-CENTRED DESIGN OF LOGIOCANDO

As we said in the previous section, the users of Logiocando are pupils of elementary schools, therefore special attention must be devoted to usability of the developed system. The system must be easy to learn and easy to work with, but also attractive and it should use a language the children find natural and suitable to them.

In order to develop a system that conform to usability criteria, we have adopted a user user-centred methodology whose basic principles are: 1) analyse users and task; 2) design and implement the system iteratively through prototypes of increasing complexity; 3) evaluate design choices and prototypes with users [4, 7]. In other words, user-centred approach requires understanding reality: who will use the system, where, how, and to do what. Then, the system is designed iterating a design-implementation-evaluation cycle. In this way it is possible to avoid serious mistakes and to save re-

implementation time, since the first design is based on empirical knowledge of user behaviour, needs, and expectations. In accordance with this methodology, we have devoted a lot of effort in collecting user information by interviewing teachers and observing children at school during several visits we conducted to the elementary school “E. De Amicis” in Bari, Italy. It is well known that acquiring user information is not an easy task and it is also very time consuming. However, a careful user and task analysis in the first phase of the system project, and also the user involvement in the evaluation of the system prototypes are the only way to make sure that the final system will conform to users’ needs and expectations.

Participatory design has also been carried out in Logiocando since teachers were involved in the design of all units [5]. They provided definitions, hints on the presentation of the theoretical concepts, examples of exercises to be implemented.

Early prototypes of Logiocando, starting with paper prototypes, have been evaluated by using several methods, primarily experts’ inspection, observation of users working with prototypes, and user interviews [5, 11, 12]. Evaluations involving teachers as well as some children were very useful to check if the adopted language, the chosen icons and the whole presentation layout of the hypermedia were easily understandable and permitted easy of work.

Before carrying out the experiment described in this paper, a pilot study was also performed, that consisted in having groups of pupils working with the system in order to observe their interaction with the hypermedia [15, 17]. This study turned out very useful since we had the opportunity to see that the children did not take seriously enough the work with Logiocando, that was considered too much a game to play with. This children attitude could actually compromise the results of the planned experiment. Therefore, together with the teachers, we carefully studied a way to make children responsible as much as possible of the work they should perform.

What we actually did was to present Logiocando very formally to the children, as a very important tool for their learning activity, clearly explaining that what they learned through the system would be carefully evaluated by their teachers. Indeed, the attitude of the children using the system as it was observed during the experiment was completely different from the one observed during the pilot study. The children were working very seriously with Logiocando, precisely executing the task they were asked to do.
The controlled experiment we carried out was aimed at evaluating the learning effectiveness of Logiocando as an instrument for revising knowledge. Indeed, Logiocando has been developed as a complement to and not as a substitute for the human teacher. The basic philosophy behind the system is to give the children the possibility of revising their knowledge and filling in eventual gaps in their understanding of a given topic (in the current implementation: elementary logic concepts).

The study aims at answering two fundamental questions by comparing the use of Logiocando with traditional lessons taught by a teacher:

1. Can the children actually improve their knowledge of logic concepts by using the hypermedia?
2. Can the hypermedia be as effective as a teacher’s lesson in revising logic concepts?

As a basic experimental hypothesis, we have predicted that Logiocando had pedagogical potentialities that could equal those of a human teacher. Indeed, even if we recognize the fundamental benefits of skilled face to face teaching, we also believe that Logiocando has peculiar advantages over traditional in-class learning, especially for revising knowledge. This assumption relies on several considerations. Some of them are those already mentioned in the introduction, as discussed by Bagui [1]. Moreover, computer-based learning is based on a one-to-one relationship, which in traditional classroom teaching is only seldom possible. Hence, pupils may take advantage of Logiocando to accommodate their specific requirements.

The following sections describe the method adopted for testing the learning effectiveness of Logiocando and report the results of the experiment.

Participants
Participants were selected and recruited from pupils attending the forth class at the elementary school “E. De Amicis” of Bari. Initially, 71 children were administered a pre-test to evaluate their knowledge on and understanding of logic. The test was developed in collaboration with the teachers of the school. It consisted of a number of open questions and some exercises referring to standard concepts of logic taught to pupils during the previous four months. Children were required to solve the problems individually in one hour as part of their class work. Then, the teachers evaluated each test individually. Final scores ranged from 0 to 10. According to the pre-test results, 40 children were selected for participating in the study. They scored below 7 in the pre-test. According to the teacher’s evaluation, they were all children who needed further exercises to improve their logic knowledge. All the pupils were familiar with the use of PCs, primarily for playing games and for navigating on Internet to find information, but nobody had previous experiences with learning hypermedia.

Design
The experiment is based on a mixed design, with pre-test post-test as the within-subjects factor, and with Teaching Method (2) as the between-subjects factor. Teaching method could be either Computer Assisted (CA) or Teacher Assisted (TA). Children were divided in two groups, composed of 20 participants each. Pupils assigned to the CA teaching method revised logic concepts individually using Logiocando. Children assigned to the TA teaching method revised logic concepts in class attending two lessons given by the teacher. Great attention has been devoted to counterbalance gender and previous knowledge on logic between the two groups. Pupils’ learning over time was evaluated by the pre-test post-test design.

Procedure
A few days before the experiment, a sample of 71 children were administered a pre-test to evaluate their previous knowledge on logic. According to the pre-test performance, 40 participants were selected and assigned to one of two Teaching Method conditions. The actual experiment was composed of two sessions, in the order: theory revision and practice. Each session lasted one hour, with a 2-day interval in between.

In the theory revision session, children assigned to the CA teaching method were required to study individually two units of the hypermedia, namely “Set operations” and “The Diagrams”. Interacting with these two units of Logiocando, they revised the basic operations on the sets and the graphical representations of the sets. The TA group was introduced exactly to the same didactic material as the CA condition, but the children attended at one hour of theory revision lesson taught by the teacher in class.

In the practice session, children were required to do some exercises on the concepts previously revised. Again, the CA group used Logiocando, while the TA group did the same exercises in class with pen and paper.

One week after the experiment, all the pupils were given a post-test as part of their class work. They had to answer a set of questions, which according to the teachers closely mirrored the pre-test one. However, to avoid carry-over effects, the wording was slightly different. In the attempt of controlling confound variables related to
the participants’ history, no other logic lessons were taught during the period of the experiment and pupils were not given any homework on the topic.

Results

Figure 1 illustrates the average value of the pre-test and of the post-test scores in the two teaching-method conditions.

![Graph showing pre-test and post-test scores for CA and TA methods](image)

**Figure 1:** Average pre-test and post-test scores as a function of Teaching Method.

The learning improvement is evident: all the children have increased their knowledge about logic. To test the significance of this effect and eventual differences between the experimental conditions, pre-test and post-test scores were entered as repeated measures in 2-way mixed design analysis of variance with Teaching Method (2) as the between-subjects factor.

Results confirmed the experimental hypothesis claiming an equal improvement over time in the two experimental conditions. The pre-test-post-test effect was highly significant \( F(1, 39) = 100.7, p < .001 \). On the contrary, the main effect of teaching method and the 2-way interaction are absolutely negligible, in both cases \( F_{11, 38} < 1 \). This implies that all the children have learnt during the experiment and that this learning is almost identical independently of the teaching method.

Table 1 further illustrates these results. It reports basic descriptive statistics related to the learning gain. The variable was computed for each participant subtracting the pre-test score from the post-test score. The first row reports the arithmetic average of the learning gain, the second one its standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>CA</th>
<th>TA</th>
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<tbody>
<tr>
<td>Mean</td>
<td>3.10</td>
<td>2.92</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.49</td>
<td>2.23</td>
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**Table 1:** Descriptive statistics of the learning gain in the 2 experimental conditions.

To conclude, our results showed that all the children significantly enhanced their knowledge during the experiment independently of the Teaching Method condition they were assigned to. The use of Logiocando has equalled the skilled performance of a human teacher allowing children to better understand logic concepts.

**DISCUSSION AND CONCLUSION**

The aim of this study was to evaluate the effectiveness of the hypermedia Logiocando and to estimate the difference between the two approaches: the computer-based one, that uses an hypermedia system, and the traditional one, that use the typical lesson in classroom. The results of the study indicate that, after using the system, the group using the hypermedia (CA group) had an excellent result.

Applying the analysis of variance to the results of the tests of all the 40 participants, we can also conclude that there is not any difference between the two approaches. The mean score of the post-test of the CA group improved of 3.1, going from 5.2 to 8.3 (see Figure 1) and the mean score of the post-test of the TA group also improved of 2.92, going from 5.23 to 8.15 (see Figure 1).

The reasons that explain these results can be various. Certainly, one is that with a learning hypermedia users can personalise their own learning path and follow their own learning rhythms. In this way, a child needing a specific period of time for learning a concept can navigate in the hypermedia for the time he or she feels necessary. Moreover, the children of the experimental group have learned as much as those of the comparison group because, enthusiastic for the computer use, they haven’t felt the inconvenience of a new type of lesson.

By considering the obtained results, we do not say that the learning hypermedia can substitute the teacher, but it can certainly be considered a valid support in the process of learning and deepening a topic.

**ACKNOWLEDGEMENT**

We would like to thank our former students Rosa Zilio and Angela Maurer, now graduates in Computer Science at the University of Bari, for their precious collaboration in the study reported in this paper.
The partial support of MURST 60% and Cofin 2000, and of the EU with grant FAIRWIS IST-1999-12641 is acknowledged.

BIBLIOGRAPHY